VegDUD project: Role of vegetation in sustainable urban development

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Abstract

In cities, the increase of artificial surfaces to the detriment of natural areas deteriorates the environmental quality and energy consumption. The VegDUD project is an interdisciplinary assessment of vegetal technics projected in the future dense city with a focus on climatology, hydrology, energy and ambiences. It aims at increasing the necessary knowledge to orientate urban planners and policy makers. The problem is tackled from several complementary points of view:
- Practises: What are the traditional and new practises of urban vegetation?
After some initial surveys we focus our researches on five families of vegetal devices.
- Tools: Can we quantify vegetation environmental impacts? What are the best spatial and temporal scales to assess them? How do they combine with urban morphology?
Urban vegetation representations are implemented in models of climatology, hydrology, sound propagation and building energy from the architectural scale up to the city scale. Measurement techniques and experimental campaigns are developed to understand the physical processes generated by new vegetation devices and to validate our models.
- Documentation: Can we rapidly acquire a sufficient knowledge of urban vegetation presence at a large scale?
We develop a communal geographical information system (GIS) to integrate the results of field surveys, propose urban development simulations and render the building-vegetation interactions in the actual and future cities.
- Analysis: What will be the long-term impacts of the present policies? What are the possible alternatives?
We compare retrospective and prospective simulations using our models. With these physical assessments, economical constraints, sensible aspects and vegetation practises are also considered.

Keywords: Microclimate, Vegetation, Instrumental observation, Numerical modelling, Physical modelling, Remote sensing,

1. Introduction

The topic of urbanization is now addressed for its negative impacts. Urban sprawl, which consumes agricultural land, leads to increased pollution of air, soil and aquatic environments as well as to more substantial hydrological risks. Sprawl contrasts with urban intensification, which, if not properly organized, can produce a degradation of quality of life of city dwellers.

In the project VegDUD, vegetation is observed as one of the possible solutions for the sustainable development of cities. Indeed, trees, green roofs, water ponds, greenswards, sustainable urban drainage systems (SUDS) are solutions that are now used by some city planners to respond to the climate challenge, because their physical behaviour is considered favourable to mitigate the urban heat island (UHI) and because of the social demand for a greener city. Even if it can be admitted that the more green a city is, the less it suffers from UHI, it is very difficult to have an objective assessment of the presence of vegetation in a city and its quantitative impact on urban climate. One of the multiple interests of natural urban surfaces lies in their capacity to dissipate energy by the way of evaporation (soil) and transpiration (plants) or evapotranspiration when both phenomena occur. This feature is mainly interesting in the case of hot climate or during summer. But this capacity is not permanently mobilized and mobilizable. Indeed, evapotranspiration requires energy to convert and water to vaporize: a dry soil does not evaporate, no more than a dry green roof. So, the

effect of a plant on the microclimate depends on its species [1], its location (climate [2] and urban insertion [1]), its growing medium [3, 4], its water provision [1]… For that reason, it is difficult to transpose results form one city to another one.
Furthermore, vegetation impacts are not limited to climate. In VegDUD, we focus on its impacts on climate, acoustics, hydrology, energy use for buildings, ambiences, and social practises.
Our project is divided in five parts. In the first one, "TYPOLOGY", we question the practises of vegetation in cities and we make an inventory of knowledge about vegetation set-ups. In the second one, "PHYSIOGRAPHY", we establish methods to acquire and manage data about vegetation presence in a city. The "MODELLING" part concerns the development of different kinds of simulation tools that enable us to estimate vegetation impacts at different scales. In the "EXPERIMENTATION" part, we collect experimental data in a district of the city of Nantes and from physical models. Finally in the "EVALUATION" part, we study evolution scenarios. The preliminary results of each part are summarized here and detailed results related to climatic approaches are presented elsewhere in the conference.

2. TYPOLOGY

What are the traditional and novel practises of the urban vegetation? How interesting are they from the climatic and urban points of view? How can we formalize the overall (environmental, social, economical) assessment of these practises?
A task group constructed a multidisciplinary documentation of vegetation set-ups and characteristics to answer these first questions. Town planners, green spaces managers, landscape architects were also questioned to know the evolutions of urban vegetation and to note what are the questions they consider in their practises. This results in a selection of set-ups on which we focus our studies:

- Green roofs and green walls,
- Greenswards versus mineral coatings,
- SUDS,
- Trees,
- Plants in contact with deep soil versus plants separated from deep soil (flower boxes, gardens above an underground parking…).

Variations of these set-ups are analysed depending on their management (extensive or intensive) and on their spatial distribution (in the street, district or city depending of the studied scale).

3. PHYSIOGRAPHY

What are the techniques allowing to rapidly get a sufficient knowledge of urban vegetation presence (areas, species) at a large scale? How can we propose realistic scenarios allowing to help taking policy decisions or to propose solutions adapted to a sustainable urban development?
The PHYSIOGRAPHY task group answer to these questions setting a geo-database from the typology constructed in the TYPOLOGY task group. To produce maps of an area of Nantes with the details of the present vegetation, several techniques are developed using different data sources. The first one consists in using multi-spectral Quickbird images with a 2.4m resolution [5]. In the second one, a semi-automatic treatment of hyper-spectral airborne data is developed. It results in a good discrimination between lawns, deciduous trees, conifers and red-leaved vegetation [6]. Another work aims at better analysing these data in the shade of buildings and trees [7]. A common Geographical Information System, ORBISGIS is developed in complementary of the spatial data infrastructure CARTAPOLIS (http://www.cartopolis.org/apps/search/?hl=en). It incorporates vegetation data from various sources and produce spatial analysis and the urban sprawl scenarios [8] including greening solutions that will be simulated with the models rendering the building-vegetation interactions.

4. EXPERIMENTATION

How to characterize the various impacts of vegetation set-ups on the environment? Are we able to highlight the impact of vegetation on city microclimate among the other components of the city? What are the suited measurement techniques?
In the EXPERIMENTATION task group, the researchers try to quantify the thermodynamical processes generated by the vegetation. Three types of experimentation are carried out: long-term surveys, intensive campaigns and studies on scale models.

4.1 Long term surveys

A sector of Nantes is equipped, since the start of the project, for the permanent survey of micro-meteorology, heat and water fluxes, quantitative hydrology of 3 embedded catchments, and pollutants transfers from the atmosphere to the waters through the surfaces [9]

4.2 Intensive campaigns

The first campaign FluxSap 2010 was performed within the same area as the long-term survey. It included 10 Eddy-covariance sensor systems, 5 Large Aperture Scintillometers, airborne (13 flights) and handheld thermal infrared measurements, hyperspectral (Hyspex) airborne measurements, 30 passive tracer dispersion exercises [10, 11, 12]. The second campaign Fluxsap 2012 was somewhat similar to the first one with the addition of a private garden intensive survey and measurements of thermal and humidity parameters along city transects and infrared imagery from two instrumented vehicles.

4.3 Studies on physical models

Three kinds of studies on physical models are carried out: green roof samples, wind tunnel urban lay-outs, reduced-scale street canyon and vegetated buildings.
Green roof samples: 6 roof configurations were implemented, including 3 types of vegetation cover, two thicknesses of growing media, and a

reference bare surface. They were compared to a classical gravel flat roof in terms of storm water management and evapotranspiration [13].

Wind Tunnel: This study focuses on an atmospheric wind tunnel simulation of the neutral boundary layer interacting with an urban-like canopy (areal density of 25%) and with a forest canopy. The measurement of velocity fields is performed using stereoscopic PIV [14]. A second step will concern the impact of tree distribution, in the urban lay out, on the flow structure and velocity field.

Climabat: A reduced-scale model (1/10) of an urban scene was built with 5 rows of hollow concrete blocks whose temperatures and radiative fluxes are permanently monitored. This model is studied in a real outdoor environment [15]. Some walls and roofs are covered with vegetation, to assess its impact both on the outdoor climate and on indoor thermal behaviour.

5. NUMERICAL MODELLING

Do we know how to represent the various impacts of vegetation set-ups on the environment? How much do the increase of artificial surfaces modify these impacts? What are the best spatial and temporal scales to assess these vegetal techniques?

This task group is implementing urban vegetation representations in models of climatology, hydrology, sound propagation, and building energy. Several scales are considered, from the architectural scale up to that of the city. We sum up here the developments already performed to adapt the models to our purposes related to urban climate.

5.1 ARPS-canopée

A multilayer urban canopy model based on a drag-force approach has been introduced in the atmospheric model ARPS in order to simulate the momentum and heat turbulent transfers between the canopy and the atmosphere [16]. A surface energy budget, including conduction through buildings' envelops is computed at each level within the canopy [17]. The inclusion of moisture transfers due to the presence of vegetation within the urban canopy layer is in progress. The applications concern scales ranging from the city to the neighbourhood and the objective is to emphasize the most efficient green set-ups and spatial arrangements and to determine the expansion degree required to have significant microclimatological impact.

5.2 TEB-Veg

A GREENROOF module was developed in TEB [18], to model the interactions between buildings and green roof systems at the scale of the city. This module describes an extensive green roof composed of three functional layers (vegetation - grass or sedum, substrate and drainage) including vegetation-atmosphere fluxes of heat, water and momentum, as well as the water and heat fluxes through the substrate and the drainage layers, and the thermal coupling with the structural envelope of the building. This new version, TEB-veg [19], can be used in combination with the Building Energy Model module within TEB [20] to assess the potential of green roofs as a sustainable adaptation strategy for cities in terms of outdoor microclimate, thermal comfort as well as energy consumption.

5.3 Solene-microclimat

The Solene-Microclimate model was developed to assess comfort in urban space (district scale). Based on the coupling of Solene [21], and code_Saturne, it includes trees [22], soil and the calculation of energy consumption for one building in the district [23]. Models representing green roofs and green walls were added, so it is now possible to assess their direct and indirect impact on building energy consumption. A complementary analysis was also performed to determine if a detailed description of airflows and temperature fields is always necessary [24].

The developed models are validated using the experimental results and are used to assess the scenarios.

6. EVALUATION

What will be the long-term impacts of the actual policies? What are the possible alternatives? What is the best effort of vegetation development with respect to ambience, energy, hydrology stakes? Can we imagine the urban vegetation as an appropriable space, adapted to the cultural organization of each society?

We will answer these questions in two task groups, EvalPRIV and EvalCOLL, dedicated to vegetation with a private use (gardens, architectural set-ups…) or a collective use (public gardens, parks…). These tasks mainly rely on comparative simulations with the models developed within the MODELLING task. The scenarios established in the TYPOLOGY task will be simulated with the appropriate models to assess the impacts of the set-ups at different scales depending of the impact under study:

- Street scale: comfort (thermal and sound), energy consumption;
- District scale: comfort, energy consumption, hydrology;
- City scale: urban heat island, climatology.

The assessments are not limited to the physical roles of the vegetation, they integrate the economical and regulation constraints, the sensible aspects and the usages of vegetation. Indeed, the sustainable development in an urban site can be isolated neither from the built environment where the citizens live, nor from the pluri-sensory experience of the users.

The final objective of these assessments is to complete the vegetation typology in order to propose an operational knowledge to orientate a climatic policy of the urban vegetation.

7. Conclusion

This work should lead to a better understanding of vegetation impacts at different scales. It yields scientific progresses concerning measurement, data analysis and modelling. So, the

experimental and numerical tools developed during this project will be available for further applications. The major progress lies in the effective interdisciplinary feature of this project.
This presentation of VegDUD is completed by 6 detailed papers about some parts of the work carried out within the project [11, 12, 13, 17, 20, 24].

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